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LABORATORY EVALUATION OF DICHLORVOS AS A SHORT-TERM PROTECTANT FOR WHEAT, SHELLED CORN, AND GRAIN SORGHUM AGAINST STORED-GRAIN INSECTS

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CONTENTS

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LABORATORY EVALUATION OF DICHLORVOS AS A SHORT-TERM PROTECTANT FOR WHEAT, SHELLED CORN, AND GRAIN SORGHUM AGAINST STORED-GRAIN INSECTS

Delmon W. LaHue[1/]

SUMMARY

Dichlorvos (2,2-dichlorovinyl dimethyl phosphate) was tested on hard red winter wheat, shelled corn, and grain sorghum as a short-term protectant against rice weevils (*Sitophilus oryzae* (L.)), red flour beetles (*Tribolium castaneum* (Herbst)), confused flour beetles (*T. confusum* Jacquelin duVal), and lesser grain borers (*Rhyzopertha dominica* (F.)). Evaluations of results were made at intervals by the determination of mortalities after aging of the deposits, by counting the number of progeny developing after toxicity test exposures, and by an assessment of progeny damage to the treated grain.

Dichlorvos at calculated deposits of 5, 10, and 20 p.p.m. was more effective against the adults of all four test-insect species on corn than on grain sorghum and wheat.

Dichlorvos did not prevent the emergence of rice weevil adults from immature forms present in infested material mixed with treated grain; however, the 20-p.p.m. application prevented the establishment of an infestation in corn 14 days after treatment and in sorghum 7 days after treatment.

Deposits of dichlorvos as high as 20 p.p.m. did not prevent the emergence of a few rice weevil adults from heavily infested corn, wheat, and sorghum. Less than 23 percent of the adult weevils that emerged were killed with the 20-p.p.m. application to wheat; however, reinfestation of the wheat by the surviving adults did not occur.

Malathion was used in the evaluations as a basis of comparison. When applied to give a calculated deposit of 10 p.p.m., it afforded excellent protection to corn and wheat for 3 months against damage by rice weevils, red and confused flour beetles, and lesser grain borers, but did not give as good protection to sorghum. The malathion application to sorghum was superior, however, to the 20-p.p.m. application of dichlorvos.

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BACKGROUND AND OBJECTIVES

In preliminary laboratory studies, dichlorvos applied at a calculated rate of 10 p.p.m. to cleaned, uninfested wheat containing 12 percent moisture afforded excellent kills of adult rice weevils and prevented the establishment of an internal infestation in exposures made immediately after treatment and 24 hours later. Kills of adult rice weevils were minimal 30 days later. Further studies with dichlorvos applied as an ultralow-volume[2/] concentrate mist and as a low-volume water emulsion spray to the surface of 3.5 bushels of shelled corn and hard red winter wheat stored in 5-cubic-foot fiberboard drums clearly demonstrated that the vapors did not penetrate the grain mass in concentrations lethal to adult rice weevils (*Sitophilus oryzae* (L.)) and confused flour beetles (*Tribolium confusum* Jacquelin duVal).

Mattson et al.[3/] state that dichlorvos as a vapor is highly toxic to insects. Strong and Sbur[4/] found dichlorvos to be the most effective compound of 11 insecticidal materials tested in reducing the total number of insects emerging from infested wheat. These authors suggested that dichlorvos, with its immediate vapor action and its limited residual life, could be included with a residual grain protectant for quick control of infestations that originate in the field. Kirkpatrick et al.[5/] state that 0.8 to 1.9 p.p.m. of dichlorvos on wheat produced 90 to 100 percent mortalities among rice weevil adults and reduced the number of progeny by 89 percent or more, and that residues of 3.8 p.p.m. or more caused 85 percent or more mortality of third- and fourth-instar larvae.

Based on these findings, tests were inaugurated with applications of dichlorvos to three different cereal grains.

The objective of this particular study was to determine the effectiveness of three dosage levels of dichlorvos against adult and immature rice weevils, adult confused flour beetles, red flour beetles, *Tribolium castaneum* (Herbst), and lesser grain borers, *Rhyzopertha dominica* (F.), when applied as an emulsion to wheat, shelled corn, and grain sorghum.

[2/] Ultralow-volume spray--undiluted emulsifiable concentrate. Low-volume spray--emulsifiable concentrate diluted with less water than is used in applying a protectant to grain.

[3/] Mattson, A. M., Spillane, J. T., and Pearce, G. W. Dimethyl 2,2-dichlorovinyl phosphate (DDVP), an organic phosphorous compound highly toxic to insects. Jour. Agr. Food Chem. 3 (4): 319-321. 1955.

[4/] Strong, R. G. and Sbur, D. E. Protective sprays against internal infestations of grain beetles in wheat. Jour. Econ. Ent. 57 (4): 544-548. 1964.

[5/] Kirkpatrick, Robert L., Harein, Phillip K., and Cooper, Curtis V. Laboratory tests with DDVP applied as a wheat protectant against rice weevils. Jour. Econ. Ent. 61 (2): 356-358. 1968.

MATERIALS AND METHODS

Cleaned, uninfested lots of hard red winter wheat, shelled corn, and grain sorghum were tempered to about 12.25 percent moisture. The individual lots were held in covered fiberboard drums at 80 ± 2° F. and 60 ± 5 percent relative humidity for 14 days for moisture equation. All moisture determinations were made on a Steinlite 512 RC moisture tester.

Test insects were reared in a room maintained at 80 ± 2° F. with a 60 ± 5 percent relative humidity. The 14-day-old rice weevil and 7-day-old lesser grain borer adults used in the tests were reared on hard red winter wheat containing about 12.5 percent moisture. The 14-day-old red and confused flour beetle adults were reared on a standard laboratory culture medium containing 10 parts white flour, 10 parts white cornmeal, and 1.5 parts brewer's yeast. Wheat from culture jars containing second-, third-, and fourth-instar rice weevil larvae were used as a source of immature rice weevils.

Lots of 1,500 grams of tempered grain were placed in 1-gallon, wide-mouth glass jars. An emulsifiable concentrate containing 40.2-percent dichlorvos (4 pounds of technical material per gallon) was diluted with neutral distilled water to make the emulsions for 1-ml. applications for the desired dichlorvos deposits of 5, 10, and 20 p.p.m. The emulsions, which were prepared immediately before use, were kept in constant agitation at 80 ± 1° F.

Applications were made with a 1-milliliter volumetric pipette to the inside wall of the 1-gallon glass jars above the grain level while the jars were turning on a 33-r.p.m. turntable (fig. 1). Immediately after application, the jars were shaken by hand for 30 seconds and then rotated for 15 minutes on a mechanical tumbler to mix the dichlorvos with the grain.

Each application was replicated at least four times, with applications being made to two separate lots of each grain. After the required aging period in covered jars, 250-gram samples were removed and placed in 1-pint glass mason jars for the toxicity exposures. The test jars were fitted with rings, 40-mesh brass screens, and filter-paper tops or lids.

Exposures were made after the deposits had aged for periods of 24 hours; 7, 14, 21 and 28 days; and 3 months. The data obtained were compared to data from insect exposures to grain treated with a malathion emulsion applied at a calculated dosage of 10 p.p.m. technical malathion and to untreated grain.

About 50 adult insects or 12 grams of wheat infested with about 100 immature rice weevils were placed in individual 250-gram samples. Ten-gram lots from each sample used for the red and confused flour beetle exposures were finely ground, replaced in the sample, and mixed by hand shaking directly before test insects were introduced.

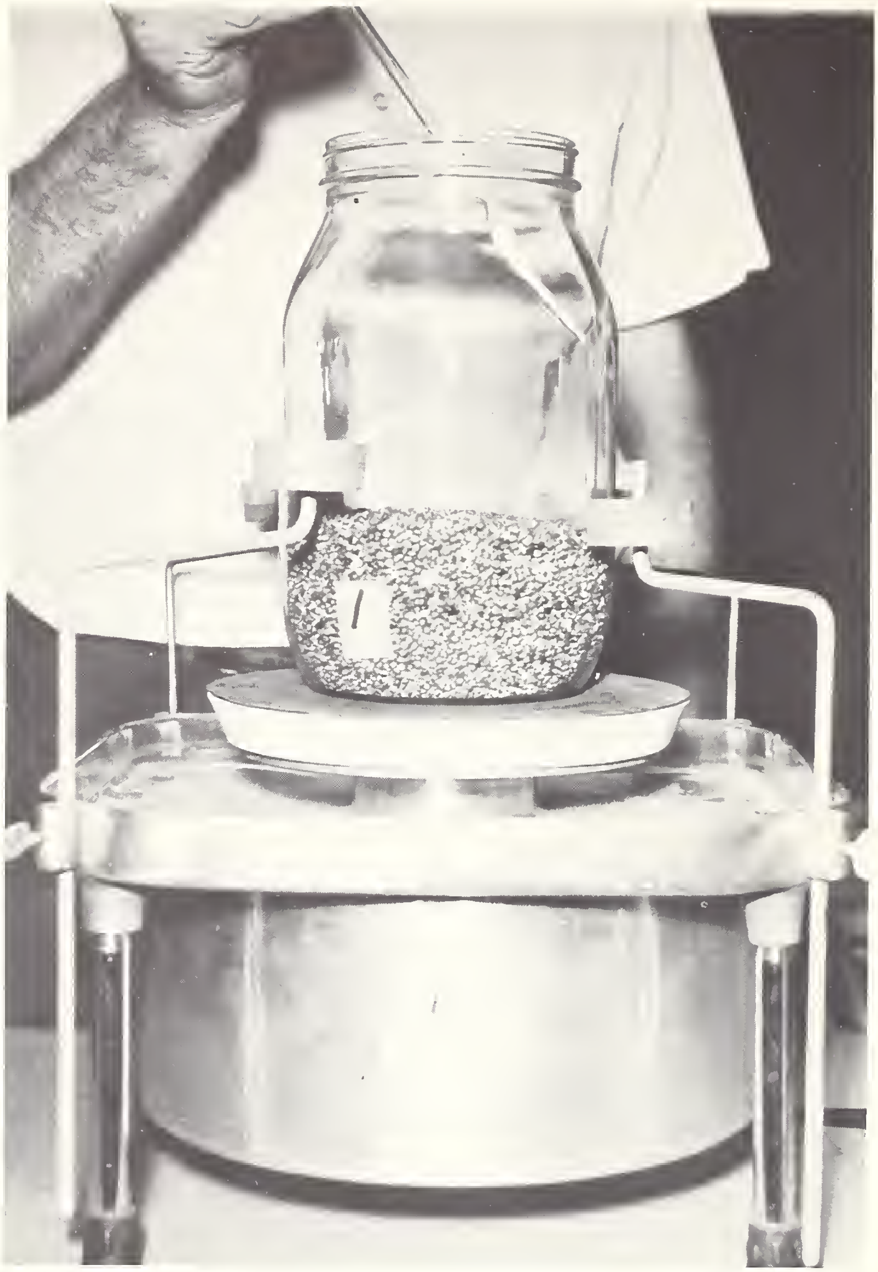

Figure 1.--Application of dichlorvos with 1-ml. pipette to inside walls of 1-gal. jar turning at 33 r.p.m. BN-35723

After 21 days' exposure, the adult insects were removed by sifting, and counts were made of the live and dead. The adults were discarded, but the grain and fine siftings were returned to the jars for a later record of progeny emergence. Counts of the progeny were recorded after peak emergence, as shown by weekly counts made in untreated samples of the different grains. After progeny readings were completed, the grain was retained for at least 120 days for an assessment of progeny damage.

Counts of the emergence of the rice weevils were made 42 days after introduction of the immature insects. The grain was also observed for progeny damage.

Four lots of 250 grams of the desired grains, each heavily infested with immature rice weevil larvae of different ages, were combined to provide 1,000-gram samples of infested grain containing first-, second-, third-, and fourth-instar larvae. Dichlorvos emulsifiable concentrate was diluted with neutral distilled water to provide desired calculated deposits of 5, 10, and 20 p.p.m. dichlorvos when applied at a rate of 1 milliliter of the emulsion to the 1,000-gram samples of the grain. Emergence data were taken over a 28-day period at 7-day intervals. All adults were held for 7 days on untreated grain before mortality data were recorded. The samples were held for an assessment of damage by continuing populations.

RESULTS

Results were evaluated by determining mortality of the adult insects, by counting the progeny, and by noting the amount of damage caused by progeny.

Rice Weevil

Table 1 compares the mortality of adult rice weevils exposed for 21 days on treated wheat, corn, and grain sorghum at spaced intervals over a 3-month period. Dichlorvos was more effective on the shelled corn than on grain sorghum and wheat. The 10-p.p.m. application to corn killed 86.8 percent of the adult rice weevils after an aging period of 28 days compared with 21.7- and 10.3-percent mortalities on sorghum and wheat, respectively. The 5-p.p.m. application to corn killed 90.6 percent of the rice weevils after 14 days' aging but killed only 41.6 percent and 22.3 percent in the sorghum and wheat samples after 14 days.

Malathion at 10 p.p.m. gave 100-percent protection for 3 months except on sorghum, where the kill was 99.3 percent at 3 months.

The 20-p.p.m. application to corn completely suppressed rice weevil progeny for 28 days; however, large numbers emerged from comparable sorghum and wheat samples after only 21 days of aging (table 2). The malathion remaining on sorghum 3 months after treatment did not prevent the development of a large number of progeny, even though 99.3 percent of the adults were killed (table 1) during the toxicity exposures. Malathion remaining on corn after 3 months prevented progeny development and subsequent damage. Malathion was slightly less effective on wheat.

Protection against rice weevil progeny damage was afforded to corn by the 20-, 10-, and 5-p.p.m. applications for 28, 14, and 7 days, respectively (table 3). Protection to sorghum by the 20-p.p.m. application was evident for 14 days. The 10-p.p.m. application to sorghum prevented damage for 7 days, but the 5-p.p.m. application lost its effectiveness after the 24-hour test. Damage by rice weevils in wheat treated with 20- and 10-p.p.m. applications appeared after aging periods of 14 and 7 days, respectively. The 5-p.p.m. treatment gave no protection against damage. The application

Table 1.--Mortality of adult rice weevils exposed for 21 days to dichlorvos on hard red winter wheat, shelled corn, and grain sorghum

Commodity, insecticide, and dosage	Mortality of insects released in grain after residue aging period of--					
	24 hours	7 days	14 days	21 days	28 days	3 months
	Percent	Percent	Percent	Percent	Percent	Percent
Wheat:1/						
Dichlorvos:						
20 p.p.m.	100.0	100.0	98.3	84.1	42.1	4.7
10 p.p.m.	98.5	90.7	81.4	13.6	10.3	6.3
5 p.p.m.	88.3	54.3	22.3	2.9	4.9	9.4
Malathion:						
10 p.p.m.	100.0	100.0	100.0	100.0	100.0	100.0
Untreated check	1.4	3.2	2.6	1.4	1.2	4.8
Corn:2/						
Dichlorvos:						
20 p.p.m.	100.0	100.0	100.0	98.1	96.6	27.1
10 p.p.m.	100.0	100.0	99.1	95.5	86.8	4.1
5 p.p.m.	100.0	100.0	90.6	27.5	6.5	2.6
Malathion:						
10 p.p.m.	100.0	100.0	100.0	100.0	100.0	100.0
Untreated check	1.2	.9	1.1	1.2	.4	2.9
Sorghum:2/						
Dichlorvos:						
20 p.p.m.	100.0	100.0	100.0	96.2	85.7	9.2
10 p.p.m.	100.0	100.0	96.0	75.7	21.7	6.3
5 p.p.m.	100.0	98.6	41.6	12.9	8.4	5.6
Malathion:						
10 p.p.m.	100.0	100.0	100.0	100.0	100.0	99.3
Untreated check	1.2	1.3	1.6	2.4	1.4	3.0

1/ Average of 9 replications.

2/ Average of 8 replications.

Table 2.--Progeny development after exposures of adult rice weevils to dichlorvos on hard red winter wheat, shelled corn, and grain sorghum

Commodity, insecticide, and dosage	Progeny emergence and mortality in grain after residue aging periods of--											
	24 hours		7 days		14 days		21 days		28 days		3 months	
	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Wheat:1/ 2/												
Dichlorvos:												
20 p.p.m.	0	-----	1.0	33.3	9.0	25.0	321.7	2.6	318.5	3.5	578.4	0.2
10 p.p.m.	0	-----	3.0	81.4	259.2	5.0	624.1	2.2	459.6	2.7	483.8	.2
5 p.p.m.	26.0	0.4	71.7	12.2	501.0	1.3	631.5	2.0	569.3	3.1	491.0	.2
Malathion:												
10 p.p.m.	0	-----	0	-----	0	-----	0	-----	0	-----	20.0	94.9
Untreated check	690.0	.1	600.0	.1	717.0	.3	816.5	.3	789.0	.2	898.5	.2
Corn:3/ 4/												
Dichlorvos:												
20 p.p.m.	0	-----	0	-----	0	-----	0	-----	0	-----	129.9	4.3
10 p.p.m.	0	-----	0	-----	0	-----	3.2	7.1	20.3	11.1	319.9	.8
5 p.p.m.	0	-----	0	-----	31.2	8.3	131.5	2.1	85.5	3.8	356.2	1.0
Malathion:												
10 p.p.m.	0	-----	0	-----	0	-----	0	-----	0	-----	0	-----
Untreated check	214.0	.9	346.2	1.3	256.7	1.1	302.2	.8	289.0	.6	346.1	1.1
Sorghum:1/ 4/												
Dichlorvos:												
20 p.p.m.	0	-----	0	-----	3.0	33.3	56.8	.6	216.0	4.3	697.5	1.3
10 p.p.m.	0	-----	0	-----	38.5	.9	416.3	1.6	760.3	1.3	783.6	1.1
5 p.p.m.	5.0	100.0	19.0	9.2	470.8	.5	801.7	1.5	845.5	.8	781.9	2.0
Malathion:												
10 p.p.m.	0	-----	0	-----	0	-----	0	-----	19.6	100.0	314.6	62.1
Untreated check	938.8	2.5	869.4	1.8	921.4	2.3	853.9	1.9	936.1	1.6	791.1	2.3

1/ Emergence during 42-day period after toxicity readings.

2/ Average of 9 replications.

3/ Emergence during 56-day period after toxicity readings.

4/ Average of 8 replications.

Table 3.--Visible damage by rice weevil progeny in samples composited from toxicity test subsamples of dichlorvos-treated hard red winter wheat, shelled corn, and grain sorghum

Commodity, insecticide, and dosage	Damage observed 120 days after aging periods of--[1]					
	24 hours	7 days	14 days	21 days	28 days	3 months
	Rating	Rating	Rating	Rating	Rating	Rating
Wheat:						
Dichlorvos:						
20 p.p.m.	0	0	0.2	4.0	4.2	5.0
10 p.p.m.	0	.8	4.2	4.8	5.0	5.0
5 p.p.m.	1.2	3.8	5.0	5.0	5.0	5.0
Malathion:						
10 p.p.m.	0	0	0	0	0	0
Untreated check	4.8	5.0	5.0	5.0	5.0	5.0
Corn:[2]						
Dichlorvos:						
20 p.p.m.	0	0	0	0	0	3.0
10 p.p.m.	0	0	0	1.0	1.5	4.0
5 p.p.m.	0	0	2.6	4.0	4.0	4.2
Malathion:						
10 p.p.m.	0	0	0	0	0	0
Untreated check	4.0	4.2	4.0	4.0	4.2	4.2
Sorghum:						
Dichlorvos:						
20 p.p.m.	0	0	0	3.0	3.8	5.0
10 p.p.m.	0	0	1.8	4.6	4.8	5.0
5 p.p.m.	0	2.2	4.6	5.0	5.0	5.0
Malathion:						
10 p.p.m.	0	0	0	0	0	2.0
Untreated check	5.0	4.8	4.8	5.0	5.0	5.0

1/ Damage rating code: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amount of insect frass and spoilage of grain.

2/ Damage observed 150 days after infestation.

of 10 p.p.m. malathion gave complete protection to corn and wheat against the establishment of rice weevil infestations; however, damage in sorghum samples treated with malathion appeared after 3 months' aging.

Records of the emergence of adult rice weevils from the samples infested with wheat containing second-, third-, and fourth-instar rice weevil larvae are given in table 4. In introductions made 24 hours after treatment, the dichlorvos vapors did not completely prevent the development and emergence of rice weevil adults even at the 20-p.p.m. dosage; however, complete mortality of the emerged adults occurred in samples of corn with the 10-p.p.m. and 20-p.p.m. applications and in sorghum with the 20-p.p.m. dosage. Adult mortality in samples of corn with the 20-p.p.m. dosage remained high for 28 days, but the numbers of adults which emerged from the infested material that had been added to the treated corn gradually increased with the increase in age of the deposit to about the number that emerged in the untreated checks.

About 50 percent of the weevils emerged in the samples with the 10-p.p.m. malathion application, but excellent kills of the emerging adults were obtained.

An assessment of the progeny damage from infestations developing from immature rice weevils introduced 24 hours after treatment shows that the 20-p.p.m. application to wheat and sorghum and the 5-, 10-, and 20-p.p.m. applications to corn prevented the establishment of damaging infestations (table 5). The 20-p.p.m. application to corn prevented damage from infestations by the immature insects introduced 7 and 14 days after treatment and to sorghum from immature insects introduced 7 days after treatment. Malathion at 10 p.p.m. gave complete protection to corn for 3 months, and only very light damage was noted in the wheat after 3 months.

Studies to determine the effect of direct applications to grain heavily infested with immature forms of the rice weevil show that deposits as high as 20 p.p.m. dichlorvos did not prevent the emergence of a few adults (table 6). Emergence quotients from wheat, corn, and sorghum treated with 20 p.p.m. were 0.17, 3.67, and 0.89 percent, respectively. Progeny damage did not occur in wheat treated with the 20-p.p.m. application, and only little progeny damage was found in wheat treated at the 10-p.p.m. rate. Corn and sorghum treated with 20 p.p.m. was slightly damaged by progeny, and the infestations which developed in these grains treated with the 5- and 10-p.p.m. applications caused considerably more damage.

Although the emergence quotients from the malathion treatment were high, all emerged adults were killed by the deposits, and the indigenous infestations were controlled.

Red Flour Beetle

In toxicity studies conducted 24 hours after treatment, complete kills of the adults were obtained in the three grains with all dosages of dichlorvos; however, a loss in effectiveness of the 5-p.p.m. dosage occurred during the next 6 days (table 7).

Table 4.--Emergence and mortality of rice weevils after exposure to dichlorvos on hard red winter wheat, shelled corn, and grain sorghum

Commodity, insecticide, and dosage	Period of aging after treatment[1/]											
	24 hours		7 days		14 days		21 days		28 days		3 months	
	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Wheat:[2/]												
Dichlorvos:												
20 p.p.m.....	16.0	87.5	14.0	64.3	27.2	30.8	133.5	0	121.0	1.7	116.2	0
10 p.p.m.....	38.0	78.9	49.0	32.6	46.0	0	109.0	.9	127.2	.8	87.4	.7
5 p.p.m.....	50.4	20.8	97.4	1.0	110.0	0	113.0	.9	96.0	3.1	89.2	.4
Malathion:												
10 p.p.m.....	44.6	100.0	52.0	100.0	64.2	98.8	53.0	98.1	62.0	96.8	64.2	98.8
Untreated check	98.0	2.0	104.0	1.0	103.2	0	108.2	0	116.2	1.0	102.0	0
Corn:[3/]												
Dichlorvos:												
20 p.p.m.....	21.5	100.0	23.8	93.7	25.0	94.0	89.5	95.5	89.8	86.9	96.3	6.9
10 p.p.m.....	55.3	100.0	22.0	85.2	25.2	81.0	93.3	4.7	110.5	4.5	101.2	4.6
5 p.p.m.....	68.5	42.3	27.2	57.8	28.5	67.0	94.5	2.1	113.7	9.7	92.1	4.9
Malathion:												
10 p.p.m.....	53.8	100.0	24.6	100.0	26.9	99.2	49.8	97.2	56.2	98.2	59.6	92.1
Untreated check	86.2	1.1	42.6	.6	39.4	.4	94.4	1.2	109.8	2.0	92.4	2.4
Sorghum:[3/]												
Dichlorvos:												
20 p.p.m.....	17.5	100.0	14.5	77.6	24.5	59.2	71.0	7.5	109.0	6.6	98.6	2.2
10 p.p.m.....	59.0	90.7	53.0	27.4	49.5	34.8	71.1	9.1	119.2	2.8	91.3	2.0
5 p.p.m.....	74.5	42.3	87.0	8.3	60.5	1.5	80.3	3.5	115.0	4.3	89.9	3.4
Malathion:												
10 p.p.m.....	41.1	100.0	46.7	100.0	50.4	94.2	59.6	91.6	56.4	96.7	63.9	90.4
Untreated check	86.6	2.0	103.0	2.6	103.2	0	96.6	2.9	109.0	1.2	88.3	.6

1/ Readings made 42 days after introduction of wheat containing immature rice weevils.

2/ Average of 9 replications.

3/ Average of 8 replications.

Table 5.--Visible damage by progeny developing from the introduction of immature rice weevils to dichlorvos on composite lots of hard red winter wheat, shelled corn, and sorghum grain

Commodity, insecticide, and dosage	Damage observed 120 days after aging periods of--[1/]					
	24 hours	7 days	14 days	21 days	28 days	3 months
	Rating	Rating	Rating	Rating	Rating	Rating
Wheat:[2/]						
Dichlorvos:						
20 p.p.m.	0	2.2	2.8	4.0	4.8	5.0
10 p.p.m.	4.0	5.0	5.0	5.0	5.0	5.0
5 p.p.m.	5.0	5.0	5.0	5.0	5.0	5.0
Malathion:						
10 p.p.m.	0	0	0	0	0	.2
Untreated check	5.0	5.0	5.0	5.0	5.0	5.0
Corn:[3/] [4/]						
Dichlorvos:						
20 p.p.m.	0	0	0	1.0	2.0	4.0
10 p.p.m.	0	2.0	2.0	4.0	4.2	5.0
5 p.p.m.	0	3.0	3.0	5.0	4.6	5.0
Malathion:						
10 p.p.m.	0	0	0	0	0	0
Untreated check	4.2	4.6	4.8	5.0	4.8	5.0
Sorghum:[3/]						
Dichlorvos:						
20 p.p.m.	0	0	1.0	3.0	4.6	5.0
10 p.p.m.	3.0	3.0	4.0	5.0	5.0	5.0
5 p.p.m.	5.0	5.0	5.0	5.0	5.0	5.0
Malathion:						
10 p.p.m.	0	0	0	0	0	1.4
Untreated check	5.0	5.0	5.0	5.0	5.0	5.0

1/ Damage rating code: 0 = visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amount of insect frass and spoilage of grain.

2/ Composites of 9 replications.

3/ Composites of 8 replications.

4/ Damage assessments made after 150 days.

Table 6.--Emergence, mortality, and progeny damage of rice weevil adults from samples of infested hard red winter wheat, shelled corn, and grain sorghum treated directly with dichlorvos

Commodity, insecticide, and dosage	Adult emergence per 1,000 g. sample	Emergence quotient 1/	Mortality after emergence	Progeny damage 2/ 3/
	Number	Percent	Percent	Rating
Wheat:				
Dichlorvos:				
20 p.p.m.....	22.6	0.17	22.73	0
10 p.p.m.....	69.8	.55	2.90	.2
5 p.p.m.....	1,309.2	10.38	.31	2.8
Malathion:				
10 p.p.m.....	2,302.2	18.24	100.00	0
Untreated check	12,619.0	-----	.18	5.0
Corn:				
Dichlorvos:				
20 p.p.m.....	124.4	3.67	26.61	.6
10 p.p.m.....	193.2	5.71	5.70	1.8
5 p.p.m.....	695.2	20.56	1.15	2.4
Malathion:				
10 p.p.m.....	913.0	27.00	100.00	0
Untreated check	3,381.0	-----	.36	4.6
Sorghum:				
Dichlorvos:				
20 p.p.m.....	122.2	.89	45.08	.6
10 p.p.m.....	1,065.8	7.81	6.38	2.2
5 p.p.m.....	2,365.2	17.34	.13	3.8
Malathion:				
10 p.p.m.....	5,966.2	43.75	100.00	0
Untreated check	13,636.6	-----	.18	5.0

1/ Number which emerged in treated sample divided by number emerging from untreated sample.

2/ Ratings made 120 days after treatment.

3/ Damage rating code: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amount of insect frass and spoilage of grain.

Table 7.--Mortality of adult red flour beetles exposed for 21 days to dichlorvos on hard red winter wheat, shelled corn, and grain sorghum

Commodity, insecticide, and dosage	Mortality of insects released in grain after residue aging period of--					
	24 hours	7 days	14 days	21 days	28 days	3 months
	Percent	Percent	Percent	Percent	Percent	Percent
Wheat:[1]						
Dichlorvos:						
20 p.p.m........	100.0	100.0	98.0	75.7	59.3	46.2
10 p.p.m........	100.0	100.0	72.4	8.3	6.7	2.6
5 p.p.m........	100.0	75.9	10.1	9.4	1.9	1.6
Malathion:						
10 p.p.m........	100.0	100.0	100.0	100.0	100.0	99.3
Untreated check...	1.2	2.2	1.7	.6	.2	.7
Corn:[2]						
Dichlorvos:						
20 p.p.m........	100.0	100.0	100.0	97.6	96.5	16.2
10 p.p.m........	100.0	100.0	100.0	99.5	94.2	3.2
5 p.p.m........	100.0	96.5	76.5	23.2	15.7	1.1
Malathion:						
10 p.p.m........	100.0	100.0	100.0	100.0	100.0	100.0
Untreated check...	1.2	1.2	.9	1.9	.8	2.6
Sorghum:[2]						
Dichlorvos:						
20 p.p.m........	100.0	100.0	99.5	96.7	84.6	22.3
10 p.p.m........	100.0	100.0	83.3	22.8	5.4	4.5
5 p.p.m........	100.0	93.7	22.3	9.0	5.7	.8
Malathion:						
10 p.p.m........	100.0	100.0	99.6	98.9	97.7	36.8
Untreated check...	.4	1.2	1.0	.6	.4	1.4

1/ Average of 9 replications.

2/ Average of 8 replications.

The 10-p.p.m. dosage on corn gave relatively good kills of the adults for 28 days but for only 7 days on wheat and sorghum. Good kills were obtained on wheat with the 20-p.p.m. application for 14 days and on sorghum for 21 days. The 10-p.p.m. application of malathion was effective on corn and wheat 3 months after treatment, but not on sorghum. Only 36.8 percent of the adults were killed at that time on sorghum.

Progeny development in the toxicity test samples was completely suppressed by the 20-p.p.m. dichlorvos application to corn in exposures made 28 days after treatment, and in wheat and sorghum in exposures made after 21 days (table 8). The 10-p.p.m. application prevented development in wheat and sorghum for 14 days and in corn for 21 days; the 5-p.p.m. application prevented development in corn and sorghum for 7 days and in wheat for 24 hours. Malathion was completely effective 3 months after treatment in wheat and corn, but some insect development occurred in sorghum samples.

Damage by red flour beetle progeny in corn with the 20-, 10-, and 5-p.p.m. treatments was completely suppressed for 28, 21, and 7 days, respectively (table 9). Damage was somewhat greater in treated wheat and sorghum, but the 20-, 10-, and 5-p.p.m. applications suppressed damage for 21, 14, and 7 days in both wheat and sorghum. The 10-p.p.m. application of malathion was effective on corn and wheat for 3 months, but some damage occurred to sorghum.

Confused Flour Beetle

The dichlorvos residues were much less effective against adult confused flour beetles than against red flour beetles. A rapid loss in effectiveness of the residues from all applications to wheat and grain sorghum occurred during the first few days of storage (table 10). Effectiveness on corn diminished gradually during storage. Malathion was very effective against adult confused flour beetles when applied to wheat and corn, but on sorghum, diminishing kills were recorded over the 3-month period.

Progeny development was suppressed in all grains for 21 days after treatment. However, large numbers developed in all samples after 28 days except corn (20 p.p.m.) where emergence was 50 percent of the untreated check (table 11).

Malathion prevented the development of progeny in corn and wheat for 3 months; a few adults emerged in comparable sorghum samples.

Malathion gave complete protection against confused flour beetle progeny damage to corn and wheat for 3 months, but sorghum sustained some damage at that time (table 12).

Lesser Grain Borer

The 10- and 20-p.p.m. dosage of dichlorvos on corn killed nearly all of the lesser grain borers 28 days after treatment, and suppressed progeny development and subsequent damage (tables 13-15). The 5-p.p.m. dosage on corn was fairly effective

Table 8.--Progeny development after exposures of adult red flour beetles to dichlorvos on hard red winter wheat, shelled corn, and grain sorghum

Commodity, insecticide, and dosage	Progeny emergence and mortality in grain after residue aging periods of--[1]											
	24 hours		7 days		14 days		21 days		28 days		3 months	
	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Wheat:[2]												
Dichlorvos:												
20 p.p.m.....	0	-----	0	-----	0	-----	0	-----	21.0	61.0	47.8	3.3
10 p.p.m.....	0	-----	0	-----	0	-----	1.2	0	48.0	41.7	66.2	.9
5 p.p.m.....	0	-----	1.3	40.0	3.5	7.1	5.0	4.0	51.0	43.1	76.6	.8
Malathion:												
10 p.p.m.....	0	-----	0	-----	0	-----	0	-----	0	-----	0	-----
Untreated check	55.0	1.8	49.2	1.2	87.0	-----	76.6	1.3	77.0	.8	83.2	1.0
Corn:[3]												
Dichlorvos:												
20 p.p.m.....	0	-----	0	-----	0	-----	0	-----	0	-----	29.9	3.4
10 p.p.m.....	0	-----	0	-----	0	-----	0	-----	5.0	20.0	56.7	1.8
5 p.p.m.....	0	-----	0	-----	1.5	16.7	6.0	9.9	41.0	1.2	52.3	2.3
Malathion:												
10 p.p.m.....	0	-----	0	-----	0	-----	0	-----	0	-----	0	-----
Untreated check	46.8	.8	59.7	1.8	62.4	.8	61.1	1.0	48.6	2.3	51.4	1.1
Sorghum:[3]												
Dichlorvos:												
20 p.p.m.....	0	-----	0	-----	0	-----	0	-----	9.0	29.6	37.0	6.3
10 p.p.m.....	0	-----	0	-----	0	-----	4.0	25.0	48.8	5.6	45.8	1.2
5 p.p.m.....	0	-----	0	-----	1.1	33.7	2.0	16.5	60.0	6.6	52.1	2.0
Malathion:												
10 p.p.m.....	0	-----	0	-----	0	-----	0	-----	0	-----	16.2	0
Untreated check	53.4	1.6	49.8	.9	54.9	.8	57.3	1.1	49.0	1.0	46.2	1.3

1/ Development during 56-day period after toxicity readings.

2/ Average of 9 replications.

3/ Average of 8 replications.

Table 9.--Visible damage by red flour beetle progeny in samples composited from toxicity test subsamples of dichlorvos-treated hard red winter wheat, shelled corn, and grain sorghum

Commodity, insecticide, and dosage	Damage observed 150 days after aging periods of--[1/]					
	24 hours	7 days	14 days	21 days	28 days	3 months
	Rating	Rating	Rating	Rating	Rating	Rating
Wheat:						
Dichlorvos:						
20 p.p.m.	0	0	0	0	1.0	1.6
10 p.p.m.	0	0	0	.2	2.0	2.0
5 p.p.m.	0	0	1.0	1.0	2.2	2.2
Malathion:						
10 p.p.m.	0	0	0	0	0	0
Untreated check	2.4	2.0	2.4	2.2	2.4	2.2
Corn:						
Dichlorvos:						
20 p.p.m.	0	0	0	0	0	1.8
10 p.p.m.	0	0	0	0	.2	2.2
5 p.p.m.	0	0	.2	.4	2.0	2.6
Malathion:						
10 p.p.m.	0	0	0	0	0	0
Untreated check	2.4	2.8	2.6	2.8	2.8	2.6
Sorghum:						
Dichlorvos:						
20 p.p.m.	0	0	0	0	.6	1.8
10 p.p.m.	0	0	0	.2	1.4	2.4
5 p.p.m.	0	0	.6	.6	2.2	2.4
Malathion:						
10 p.p.m.	0	0	0	0	0	.6
Untreated check	2.4	2.6	2.2	2.0	2.6	2.2

1/ Damage rating code: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amount of insect frass and spoilage of grain.

Table 10.--Mortality of adult confused flour beetles exposed for 21 days to dichlorvos on hard red winter wheat, shelled corn, and grain sorghum

Commodity, insecticide, and dosage	Mortality of insects released in grain after residue aging periods of--					
	24 hours	7 days	14 days	21 days	28 days	3 months
	Percent	Percent	Percent	Percent	Percent	Percent
Wheat:1/						
Dichlorvos:						
20 p.p.m.	100.0	96.2	20.1	8.0	3.5	6.0
10 p.p.m.	100.0	52.9	5.9	1.9	1.4	3.2
5 p.p.m.	100.0	3.0	5.1	3.9	.5	3.2
Malathion:						
10 p.p.m.	100.0	100.0	100.0	99.6	99.6	93.6
Untreated check	0	2.4	1.1	2.0	1.0	2.4
Corn:2/						
Dichlorvos:						
20 p.p.m.	100.0	100.0	96.5	86.1	56.7	10.9
10 p.p.m.	100.0	92.5	64.8	40.8	11.1	.9
5 p.p.m.	98.0	44.8	12.5	1.5	.5	.6
Malathion:						
10 p.p.m.	100.0	100.0	100.0	100.0	100.0	92.4
Untreated check	0	.3	.6	1.1	.7	1.1
Sorghum:2/						
Dichlorvos:						
20 p.p.m.	100.0	97.1	47.3	17.4	2.0	2.2
10 p.p.m.	100.0	64.9	18.0	5.8	1.9	2.1
5 p.p.m.	97.1	11.3	9.6	1.4	.9	1.6
Malathion:						
10 p.p.m.	85.2	79.6	78.6	66.4	59.5	16.2
Untreated check	0	1.2	.8	2.2	1.8	.4

1/ Average of 9 replications.

2/ Average of 8 replications.

Table 11.--Progeny development after exposures of adult confused flour beetles to dichlorvos on hard red winter wheat, shelled corn, and grain sorghum

Commodity, insecticide, and dosage	Progeny emergence and mortality in grain after residue aging periods of--[1]											
	24 hours		7 days		14 days		21 days		28 days		3 months	
	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Wheat:[2]												
Dichlorvos:												
20 p.p.m.	0	-----	0	-----	0.5	0	0	-----	45.5	0.7	40.0	0.1
10 p.p.m.	0	-----	0	-----	1.8	0	5.2	9.5	46.0	0	48.5	.1
5 p.p.m.	0	-----	1.5	0	2.5	0	5.0	5.0	50.0	2.0	56.5	.1
Malathion:												
10 p.p.m.	0	-----	0	-----	0	-----	0	-----	0	-----	0	-----
Untreated check	59.0	0	52.8	1.9	63.0	.2	54.0	1.1	61.0	0	62.4	.5
Corn:[3]												
Dichlorvos:												
20 p.p.m.	0	-----	0	-----	0	-----	1.0	0	25.0	1.0	29.2	2.4
10 p.p.m.	0	-----	0	-----	1.0	0	1.5	0	43.5	1.1	49.6	2.3
5 p.p.m.	0	-----	5.6	21.7	8.3	6.1	14.0	1.8	59.0	2.5	58.4	1.9
Malathion:												
10 p.p.m.	0	-----	0	-----	0	-----	0	-----	0	-----	0	-----
Untreated check	56.4	1.2	49.8	.7	53.4	1.0	46.3	1.9	51.2	2.2	54.7	1.3
Sorghum:[3]												
Dichlorvos:												
20 p.p.m.	0	-----	0	-----	0	-----	5.0	0	48.0	2.6	62.8	1.8
10 p.p.m.	0	-----	0	-----	0	-----	7.5	20.0	51.0	.5	59.0	.7
5 p.p.m.	0	-----	11.0	36.4	6.0	5.6	10.0	5.0	56.8	.4	66.3	.8
Malathion:												
10 p.p.m.	0	-----	0	-----	0	-----	0	-----	0	-----	7.0	0
Untreated check	59.5	.2	58.7	.7	61.6	.8	53.4	1.0	62.8	1.7	58.2	.9

1/ Development during 63-day period after toxicity readings.

2/ Average of 9 replications.

3/ Average of 8 replications.

Table 12.--Visible damage by confused flour beetle progeny in samples composited from toxicity test subsamples of dichlorvos-treated hard red winter wheat, shelled corn, and grain sorghum

Commodity, insecticide, and dosage	Damage observed 150 days after aging periods of--[1/]					
	24 hours	7 days	14 days	21 days	28 days	3 months
	Rating	Rating	Rating	Rating	Rating	Rating
Wheat:						
Dichlorvos:						
20 p.p.m.	0	0	0	0	1.0	1.8
10 p.p.m.	0	0	.4	.6	1.4	2.6
5 p.p.m.	0	1.0	.6	1.4	2.4	2.4
Malathion:						
10 p.p.m.	0	0	0	0	0	0
Untreated check	2.1	2.2	2.1	2.3	2.7	2.6
Corn:						
Dichlorvos:						
20 p.p.m.	0	0	0	0	.2	1.8
10 p.p.m.	0	0	.2	.2	1.2	2.2
5 p.p.m.	0	.2	.8	1.4	2.0	2.4
Malathion:						
10 p.p.m.	0	0	0	0	0	0
Untreated check	2.2	2.6	2.4	2.2	2.4	2.6
Sorghum:						
Dichlorvos:						
20 p.p.m.	0	0	0	.2	1.0	2.0
10 p.p.m.	0	.2	.2	.4	1.6	2.2
5 p.p.m.	0	.4	.4	1.6	2.4	2.6
Malathion:						
10 p.p.m.	0	0	0	0	0	.4
Untreated check	2.2	2.0	2.2	2.0	2.4	2.6

[1/] Damage rating code: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amount of insect frass and spoilage of grain.

Table 13.--Mortality of adult lesser grain borers exposed for 21 days to dichlorvos on hard red winter wheat, shelled corn, and grain sorghum

Commodity, insecticide, and dosage	Mortality of insects released in grain after residue aging period of--					
	24 hours	7 days	14 days	21 days	28 days	3 months
	Percent	Percent	Percent	Percent	Percent	Percent
Wheat:[1]						
Dichlorvos:						
20 p.p.m.	100.0	100.0	99.5	95.7	45.9	18.6
10 p.p.m.	100.0	100.0	95.1	85.1	20.3	4.7
5 p.p.m.	100.0	97.6	82.0	73.6	2.5	4.9
Malathion:						
10 p.p.m.	100.0	100.0	100.0	100.0	99.6	91.4
Untreated check	7.1	1.3	1.4	1.8	3.2	1.9
Corn:[2]						
Dichlorvos:						
20 p.p.m.	100.0	100.0	100.0	100.0	94.5	29.4
10 p.p.m.	100.0	100.0	100.0	100.0	91.9	3.7
5 p.p.m.	100.0	98.1	94.6	71.8	21.2	2.1
Malathion:						
10 p.p.m.	100.0	100.0	100.0	100.0	100.0	100.0
Untreated check	2.8	1.9	2.5	1.8	2.7	4.2
Sorghum:[2]						
Dichlorvos:						
20 p.p.m.	100.0	100.0	100.0	100.0	84.1	7.2
10 p.p.m.	100.0	100.0	98.1	92.3	30.2	5.6
5 p.p.m.	100.0	95.1	67.3	40.9	7.3	2.1
Malathion:						
10 p.p.m.	100.0	100.0	100.0	100.0	95.3	79.6
Untreated check	4.9	3.8	6.7	5.3	3.6	3.5

1/ Average of 9 replications.

2/ Average of 8 replications.

Table 14.--Progeny development after exposures of adult lesser grain borers to dichlorvos on hard red winter wheat, shelled corn and grain sorghum

Commodity, insecticide, and dosage	Progeny emergence and mortality in grain after residue aging periods of--[1]											
	24 hours		7 days		14 days		21 days		28 days		3 months	
	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead	Emergence	Dead
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Wheat:[2]												
Dichlorvos:												
20 p.p.m......	0	-----	0	-----	0	-----	0	-----	37.2	5.3	362.3	2.2
10 p.p.m......	0	-----	0	-----	.5	0	5.5	4.5	183.6	1.8	379.4	1.9
5 p.p.m......	0	-----	0	-----	55.7	2.2	272.0	2.8	575.8	1.9	408.8	1.8
Malathion:												
10 p.p.m......	0	-----	0	-----	0	-----	0	-----	0	-----	1.2	100.0
Untreated check	350.0	1.2	482.2	5.9	814.4	10.6	514.4	2.7	479.2	2.6	561.4	5.4
Corn:[3]												
Dichlorvos:												
20 p.p.m......	0	-----	0	-----	0	-----	0	-----	1.2	20.0	49.3	1.9
10 p.p.m......	0	-----	0	-----	0	-----	0	-----	5.5	4.5	56.4	2.2
5 p.p.m......	0	-----	9.1	40.5	9.7	15.1	12.5	20.0	37.5	4.1	66.7	1.1
Malathion:												
10 p.p.m......	0	-----	0	-----	0	-----	0	-----	0	-----	0	-----
Untreated check	69.4	1.8	73.2	2.6	49.6	2.0	57.4	1.8	59.3	2.2	63.9	2.0
Sorghum:[3]												
Dichlorvos:												
20 p.p.m......	0	-----	0	-----	0	-----	0	-----	9.2	10.8	416.0	5.6
10 p.p.m......	0	-----	0	-----	0	-----	2.0	16.5	60.5	3.7	582.0	3.4
5 p.p.m......	0	-----	0	-----	11.0	0	71.5	3.5	362.3	5.8	624.1	4.2
Malathion:												
10 p.p.m......	0	-----	0	-----	0	-----	0	-----	24.0	4.2	129.8	5.6
Untreated check	791.1	4.7	841.5	3.9	569.9	4.1	686.5	3.9	548.6	6.1	599.0	5.3

1/ Emergence during 56-day period after toxicity readings.

2/ Average of 9 replications.

3/ Average of 8 replications.

Table 15.--Visible damage by lesser grain borer progeny in samples composited from toxicity test subsamples of dichlorvos-treated hard red winter wheat, shelled corn, and grain sorghum

Commodity, insecticide, and dosage	Damage observed 150 days after aging period of--[1]					
	24 hours	7 days	14 days	21 days	28 days	3 months
	Rating	Rating	Rating	Rating	Rating	Rating
Wheat:						
Dichlorvos:						
20 p.p.m.	0	0	0	0	3.0	4.5
10 p.p.m.	0	0	0	.2	4.0	4.8
5 p.p.m.	0	0	5.0	5.0	5.0	5.0
Malathion:						
10 p.p.m.	0	0	0	0	0	0
Untreated check	5.0	5.0	5.0	5.0	5.0	5.0
Corn:						
Dichlorvos:						
20 p.p.m.	0	0	0	0	.2	2.6
10 p.p.m.	0	0	0	0	.4	3.4
5 p.p.m.	0	.2	.4	.6	2.0	4.2
Malathion:						
10 p.p.m.	0	0	0	0	0	0
Untreated check	4.4	4.2	4.0	4.2	4.0	4.6
Sorghum:						
Dichlorvos:						
20 p.p.m.	0	0	0	0	1.2	4.2
10 p.p.m.	0	0	0	.2	4.0	5.0
5 p.p.m.	0	0	1.2	3.6	5.0	5.0
Malathion:						
10 p.p.m.	0	0	0	0	.6	2.6
Untreated check	4.0	4.2	5.0	5.0	4.8	4.8

[1] Damage rating code: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amount of insect frass and spoilage of grain.

for about 14 days but did not prevent some progeny development and damage. The 10- and 20-p.p.m. dosage on wheat and sorghum gave protection for 21 days even though some progeny development occurred, but the 5-p.p.m. dosage was effective for only 7 days.

Malathion was completely effective on corn and wheat for 3 months, but on sorghum its effectiveness declined in tests conducted after 21 days' storage.

CONCLUSION

The findings indicate that dichlorvos, with its immediate vapor action and limited residual life, applied at a calculated dosage of 20 p.p.m. would eliminate most of the insects commonly found in infested grain. Therefore, potential use would be restricted to instances where only an initial cleanup is required, or application could be made along with a longer lasting material to give long-term protection against reinfestation.

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